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Technical Report
66-2922

Interim Report

THE EFFECTS OF A MUZZLE BRAKE'S DIAMETER & LENGTH ON OVERPRESSURE & EFFICIENCY

TECHNICAL REPORT

By

Mark J. Salsbury

October 1966

U. S. ARMY WEAPONS COMMAND

ROCK ISLAND ARSENAL

RESEARCH & ENGINEERING DIVISION

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TECHNICAL REPORT

66-2920

INTERIM REPORT

THE EFFECTS OF A MUZZLE BRAKE'S DIAMETER & LENGTH ON OVERPRESSURE & EFFICIENCY

BY

MARK J. SALSBURY

DEVELOPMENT ENGINEERING BRANCH

OCTOBER 1966

D.A. No. 1-W-5-23801-A-290 A.M.S. Code No. 5523.11.44000.01

ABSTRACT

This is an interim report on an overall study of single and multi-baffled brakes. The intent of this study is to isolate and examine each muzzle brake parameter to determine its effect on efficiency and overpressure for the purpose of developing an optimum brake geometry which will maintain efficiency and reduce overpressures on the crew area. The parameters with which this test dealt were the brake's deflector diameter and its location with respect to the muzzle.

The most important finding of this study is that there exists a downstream loci of points between 1.5 and 2.5 calibers at which a baffle can be placed and maintain a relatively constant efficiency and that at 2.5 calibers, a baffle will produce almost 16 percent less overpressure than it does at 1.5 calibers.

This optimum geometry in which a reduction in overpressure is obtained without loss of efficiency can be applied to all conventional brakes.

FOREWORD

Authorization for this muzzle brake study was granted by D.A. Project No. 1-W-5-23801-A-290.

The value of this study lies in the fact that each brake parameter will be studied separately to determine its effect on efficiency and overpressure, whereas most previous attempts at reducing overpressure have only dealt with mass rate of flow and the brake's angle of deflection.

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OBJECT

The object of this test, which is only a portion of an overall muzzle brake study, was to determine what effects a brake diameter and location have on its efficiency and back blast. The objective of the entire study is to develop an optimum brake configuration which would have a high efficiency and yet not produce excessively high overpressure in the crew area.

INTRODUCTION

Many previous investigations, both theoretical and experimental have been made in the area of muzzle brake efficiency. Few theoretical studies, however, have been directed towards the problem of reducing the back blast which high efficiency brakes produce.

From the standpoint of efficiency, the optimum brake design is basically a plate positioned in front of the gun muzzle having enough area to deflect rearward all of the escaping muzzle gases. Since this situation isn't possible in practice because of gas escape through the brake's projectile port, one must move the deflector plate downstream from the muzzle until a negligible amount of gas escapes in this manner. However, as the plate is moved further from the muzzle, its diameter must be increased to prevent gas from escaping around its extremities. Unfortunately, a plate that could fulfill these requirements would be much too large for practical application and a compromise between weight and efficiency must be made. It would follow, therefore, from the previous discussion, that for any predetermined distance between muzzle and baffle an optimum baffle diameter exists; and for every baffle diameter there is an optimum distance.

Little is known about how a brake's diameter and length affect overpressure. In the past, overpressure has usually been associated with a brake's basic efficiency or its deflection angles; the correlation being that the higher a brake's efficiency or the greater its angle of deflection, the higher the overpressure. It was the aim of this study, therefore, to determine if an optimum configuration of brake diameter and location does exist for overpressure as it does for efficiency and if so, determine if these two configurations could be compromised.

The measure of efficiency used for these tests was momentum index (b) which is defined by the following equations:

$$\text{Momentum index (b)} = 1 - \frac{\text{(momentum imparted during gas) (ejection period with a brake)}}{\text{(momentum imparted during gas) (ejection period without a brake)}}$$

$$b = 1 - \frac{(M_{R1}\, V_{R1}) - (M_p + M_{c/2})\, V_o}{(M_{R2}\, V_{R2}) - (M_p + M_{c/2})\, V_o} \qquad \text{(Eq. 1)}$$

$M_{R1}\, V_{R1}$ = total momentum imparted to recoiling parts with a brake.

$M_{R2}\, V_{R2}$ = total momentum imparted to recoiling parts without a brake.

$(M_p + M_{c/2})\, V_o$ = Momentum imparted to recoiling parts up to gas ejection period.

where M_{R1} = mass of recoiling parts with a brake.

M_{R2} = mass of recoiling parts without a brake.

M_p = mass of projectile

M_c = mass of charge

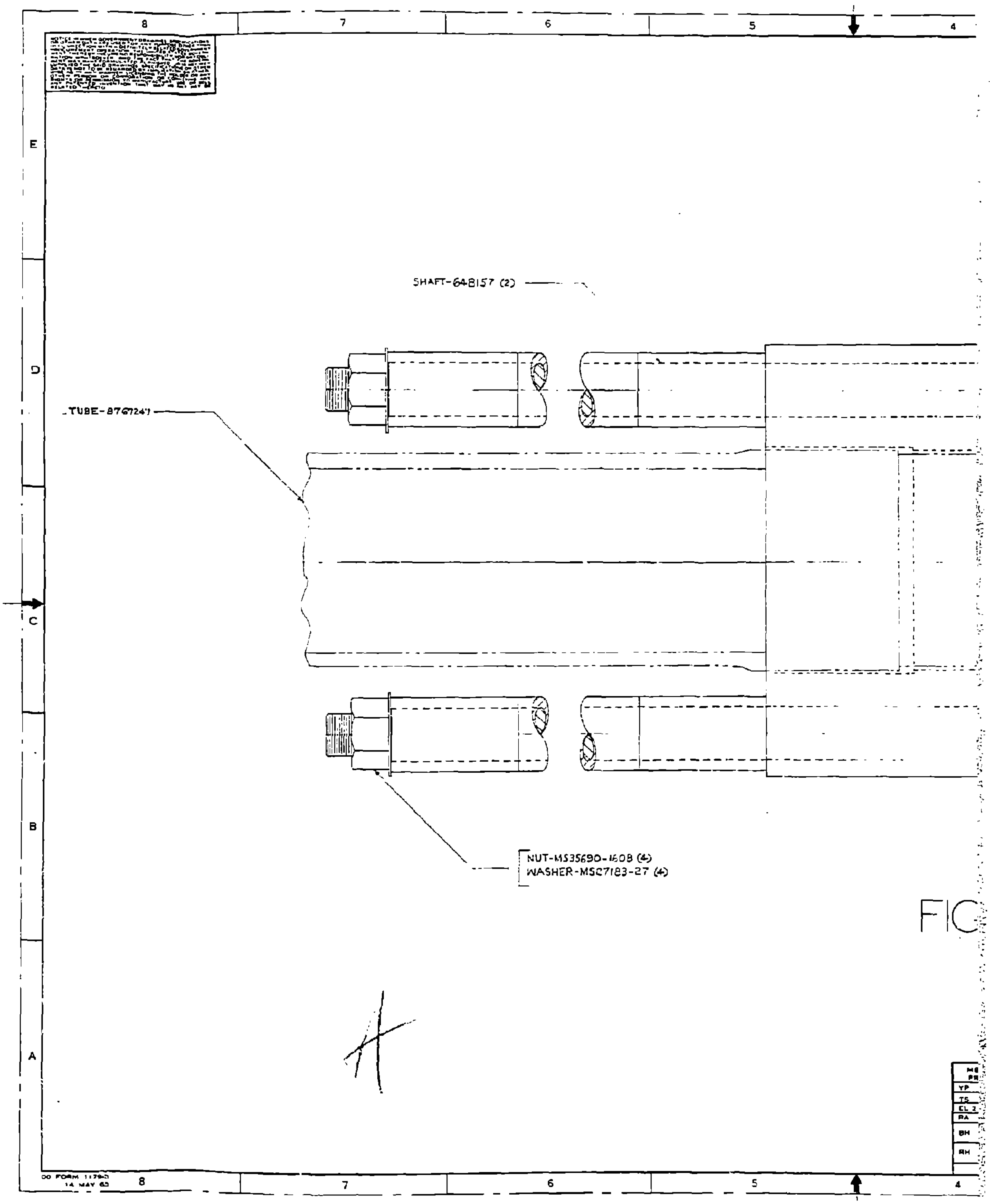
V_{R1} = maximum recoil velocity with a brake.

V_{R2} = maximum recoil velocity without a brake.

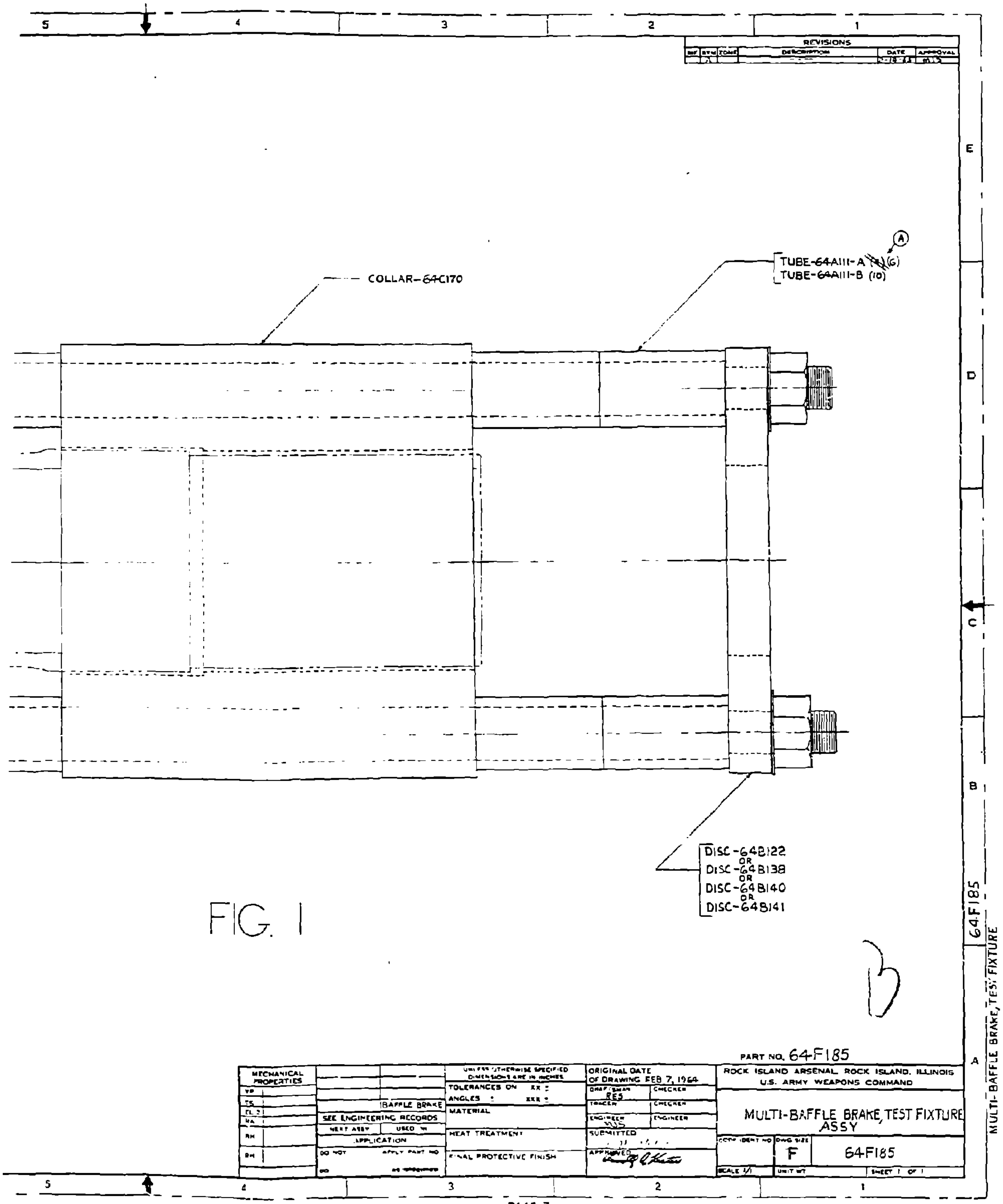
V_o = muzzle velocity of projectile.

EQUIPMENT

The muzzle brake test fixture used in this study had three (3) removable deflectors or discs. These discs had outside diameters of 15.0, 20.0, and 25.0 inches and inside diameters of 4.25 inches. These were attached by four (4) rods to a muzzle collar and could be positioned at various distances from the muzzle with spacers. (See Figure 1). The test shots were fired from a 105mm howitzer which rolled on the free recoil mount shown in Figure 2. Two conventional brakes were also tested for comparison purposes, the 5K (medium efficiency) brake and the M2A2E2 (low efficiency) brake. (See Figures 3 & 4). Overpressure was measured with piezo-electric pencil gages which were arranged in positions shown in Figure 5. A list of the instrumentation equipment used and procedures followed is presented in the Appendix.



SHAFT-648157 (2)
TUBE-8767241
NUT-MS35690-1608 (4)
WASHER-MS27183-27 (4)
FIG



REVISIONS
COLLAR-64C170
TUBE-64A111-A (6)
TUBE-64A111-B (10)
DISC-64B122
OR
DISC-64B138
OR
DISC-64B140
OR
DISC-64B141
PART NO. 64-F185
MECHANICAL PROPERTIES
BAFFLE BRAKE
SEE ENGINEERING RECORDS
NEXT ASSY
USED ON
APPLICATION
TOLERANCES ON
ANGLES
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH
ORIGINAL DATE OF DRAWING FEB 7, 1964
DRAFTSMAN RES
CHECKER
TRACER
ENGINEER
SUBMITTED
APPROVED
ROCK ISLAND ARSENAL, ROCK ISLAND, ILLINOIS
U.S. ARMY WEAPONS COMMAND
MULTI-BAFFLE BRAKE, TEST FIXTURE ASSY
DWG SIZE F
64F185
SCALE 1/1
UNIT WT
SHEET 1 OF 1
64F185
MULTI-BAFFLE BRAKE, TEST FIXTURE

FIG. 1

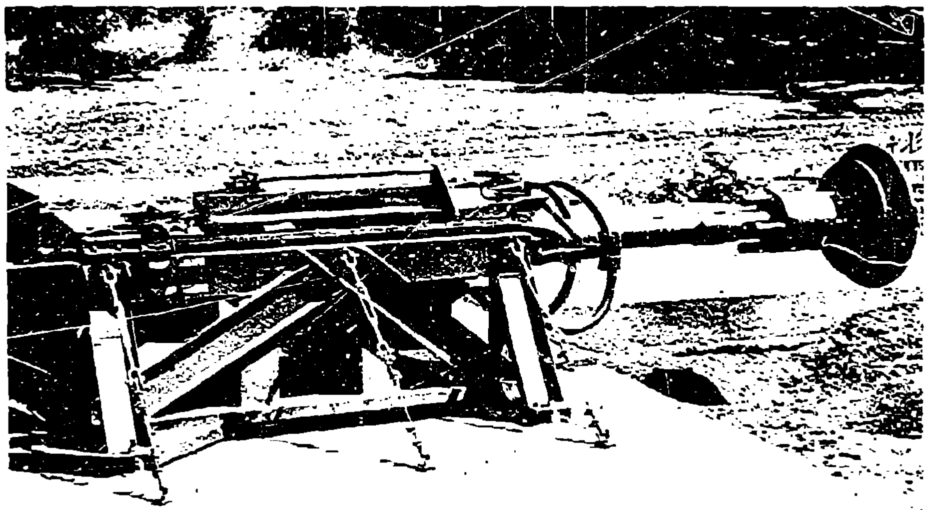


Figure 2
105mm Howitzer With Multi-Baffled Brake
Installed on Free Recoil Mount at RIA T&E Range

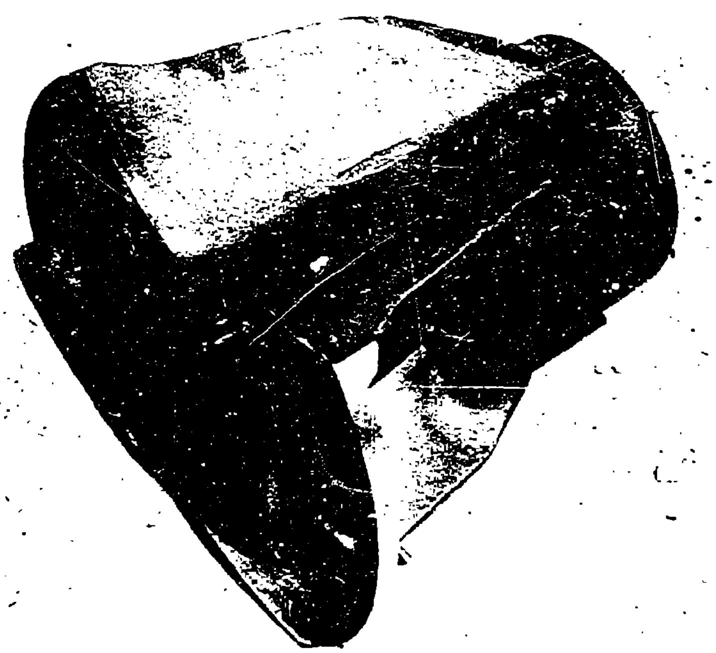


Figure 3
5-K Medium Efficiency Muzzle Brake
(WTV-F10785)

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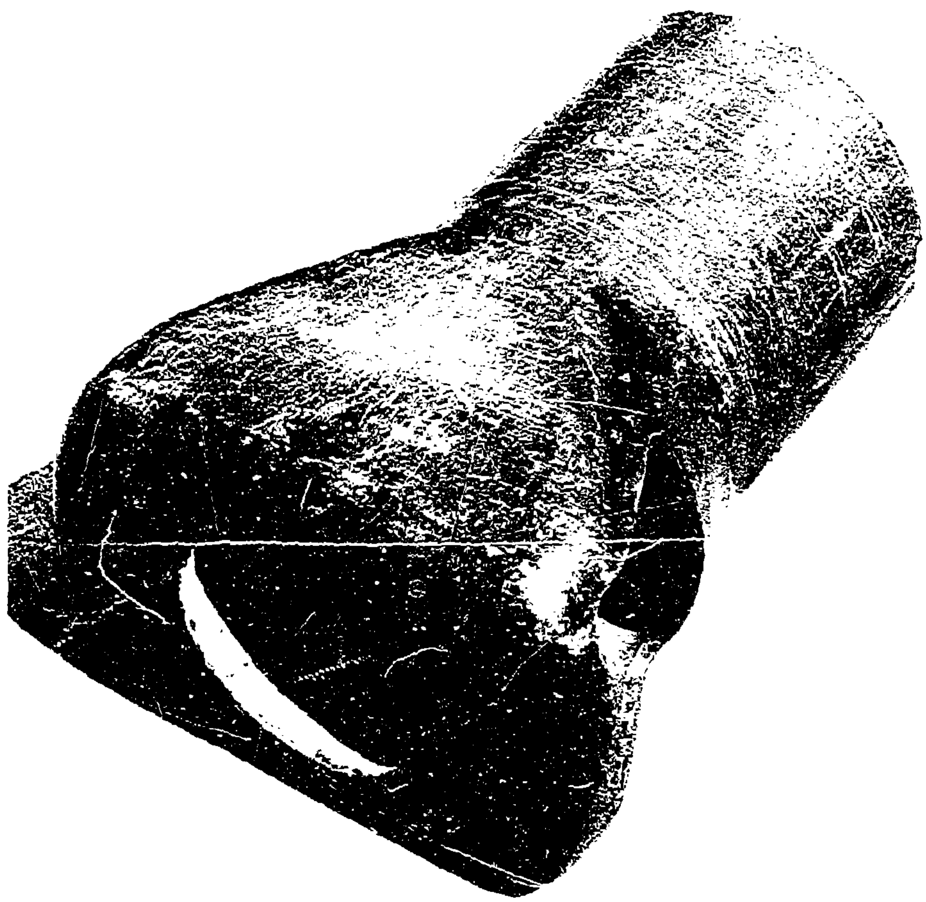


Figure 4

M2A2E2 Low Efficiency Muzzle Brake

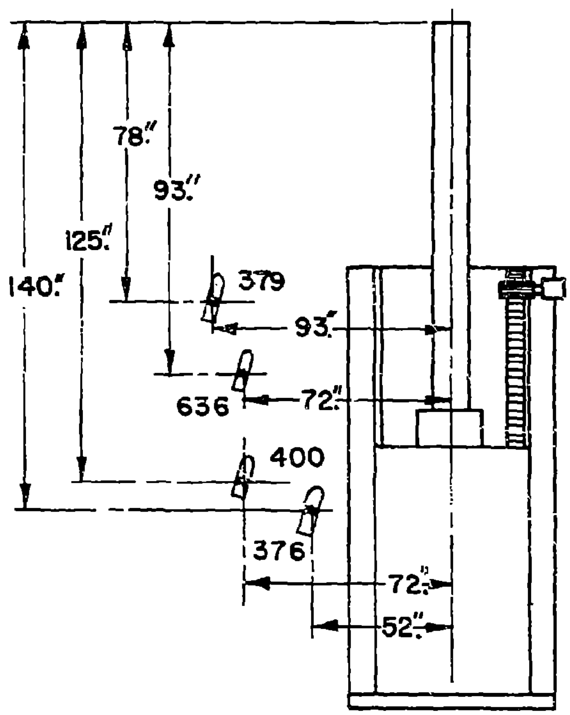


FIGURE 5
PRESSURE GAUGE LOCATIONS

PROCEDURE

This investigation was divided into four phases:

1. Firing without a brake, with the 5-K brake, and with the M2A2E2 brake.

2. Firing test brake with one disc only.

3. Firing test brake with disc combinations of two.

4. Firing test brake with disc combinations of three.

Phase 1: The testing began by firing six rounds from the 105mm howitzer using no brake attachment. The charge used throughout all of the firings was a standard zone 7 charge with T36 propellant. Four rounds were then fired with both the 5-K and the M2A2E2 brake. For every round fired in the test, the muzzle velocity, recoil velocity, and overpressure (Δ P) in the crew area was measured. Also, during this first phase, the static friction load of the free recoil mount was determined.

Phase 2: During this single baffle portion of the experiment, each brake was tested at positions 3.0, 6.0, 9.0, 12.0, and 15.0 inches downstream from the muzzle with four rounds being fired at each position. The spacing interval of 3 inches was chosen based on pre-test firings. Three inches proved to be the smallest increment change for which difference in recoil velocity could be resolved with the instrumentation in use. Instrumentation limitations also cancelled out initially planned zone 4 firings which would have added a third parameter into the test. The test settings for all four phases are presented in Tabel I.

Phase 3: In this portion of the test, which incorporated double baffle combinations, the first disc (that closest to the muzzle) was placed at its maximum efficiency position and the second disc tested at 3.0, 6.0, and 8.0 inches downstream from the first. The optimum position for the first disc was determined from Phase 2. A listing of double baffle combinations is presented in Table I.

Phase 4: This phase of the test dealt with triple baffle combinations with the first and second disc placed at their maximum efficiency positions. As before, the optimum locations were determined from preceeding tests. Because the muzzle brake test fixture was only 15 inches long, the third disc could only be tested at one position. The triple baffle combinations are presented in Table I.

<u>TABLE I</u>

PHASE	BRAKE CONFIGURATION	TOTAL NO. OF ROUNDS
1	No brake	6
	5-K (Medium Efficiency)	4
	M2A2E2 (Low Efficiency)	4
2 Single Baffle	15 in. disc at 3, 6, 9, 12, and 15 in. from muzzle	20
	20 in. disc at 3, 6, 9, 12, and 15 in. from muzzle	20
	25 in. disc at 3, 6, 9, 12, and 15 in. from muzzle	20
3 Double Baffle Combinations	15 in. disc at 6 in. and 20 in. disc at 9, 12, and 15	12
	15 in. disc at 6 in. and 25 in. disc at 9, 12, and 15	12
	20 in. disc at 6 in. and 15 in. disc at 9, 12, and 15	12
	20 in. disc at 6 in. and 25 in. disc at 9, 12, and 15	12
	25 in. disc at 6 in. and 15 in. disc at 9, 12, and 15	12
	25 in. disc at 6 in. and 20 in. disc at 9, 12, and 15	12
4 Triple Baffle Combinations	15 in disc at 6 in, 20 in disc at 12 in, 25 in disc at 15 in	4
	15 in disc at 6 in, 25 in disc at 12 in, 20 in disc at 15 in	4
	20 in disc at 6 in, 15 in disc at 12 in, 25 in disc at 15 in	4
	20 in disc at 6 in, 25 in disc at 12 in, 15 in disc at 15 in	4
	25 in disc at 6 in, 15 in disc at 12 in, 20 in disc at 15 in	4
	25 in disc at 6 in, 20 in disc at 12 in, 15 in disc at 15 in	4

<u>DATA</u>

The total mass of recoiling parts with various brake attachments:

M_R without brake	83.12 Slugs	M_R with 25 in. disc	94.01 Slugs
M_R with 5-K brake	85.41 Slugs	M_R with 15 & 20 in. disc	93.83 Slugs

DATA

M_R with M2A2E2 brake	84.57 Slugs	M_R with 15 & 25 in. disc	95.38 Slugs
M_R with 15 in. disc	91.25 Slugs	M_R with 20 & 25 in. disc	96.59 Slugs
M_R with 20 in. disc	92.46 Slugs	M_R with 15,20 & 25 in. disc	97.96 Slugs

$M_p + Mc/2 = 1.072$ Slugs

$V_o = 1605. \pm 5$ fps

$V_{R2} = 23.68$ fps $\pm$ .13 fps (established in Phase 1)

$(M_p + Mc/2)\ V_o = 1720.56$ lb-sec (established in Phase 1)

$(M_{R2}\ V_{R2}) = 1968.28$ lb-sec (established in Phase 1)

$(M_{R2}\ V_{R2}) - (M_p + Mc/2)\ V_o = 253.31$ lb-sec (established in Phase 1)

F = static friction load of recoil mount = 150.0 lbs

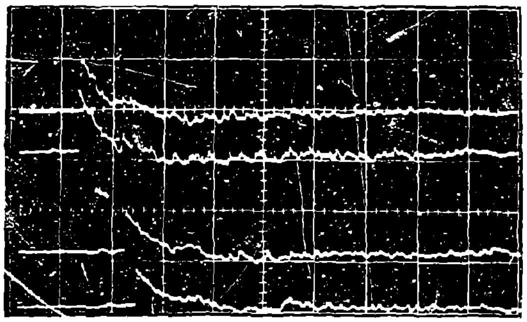
t = time at which maximum recoil velocity is reached = .04 sec

l_F = frictional impulse of system = 6.00 lb-sec

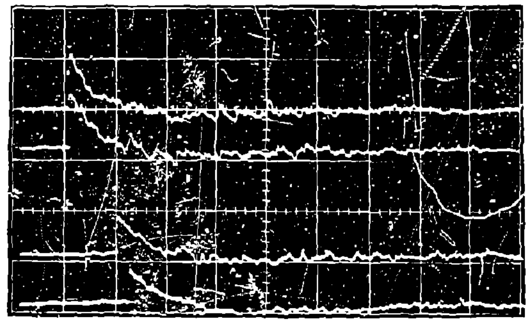
The frictional impulse was included in the calculations of momentum index.

$$b = 1 - \frac{(M_{R1}\ V_{R1}) + l_F - (M_p + Mc/2)\ V_o}{(M_{R2}\ V_{R2}) + l_F - (M_p + Mc/2)\ V_o} \qquad \text{(Eq. 2)}$$

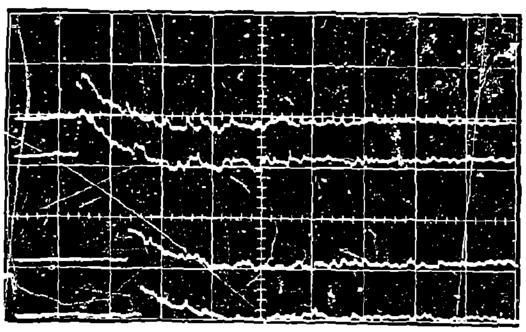
In Table II, the recoil velocity (V_{R1}) momentum index (b), and crew area overpressure (ΔP) is given for every brake configuration tested. The recoil velocities presented here are average values for four rounds. The values of P, however, were exactly the same for all four rounds for any given configuration. A sample of five oscilloscope traces from which these values were determined is presented in Figures 6a through 6e. Only overpressure data taken on Gage 636 (second trace down from top) is presented in Table II. Gage 636 was chosen as the representative sample because its location with respect to the muzzle is one which is commonly used in crew area overpressure measurement and, therefore, can be easily compared with the data of other studies. It can be seen that Gage 636 and Gage 379, which were located in the same approximate area, were in close agreement. Gage 379 is represented by the topmost oscilloscope trace and had the same calibration factor as Gage 636.



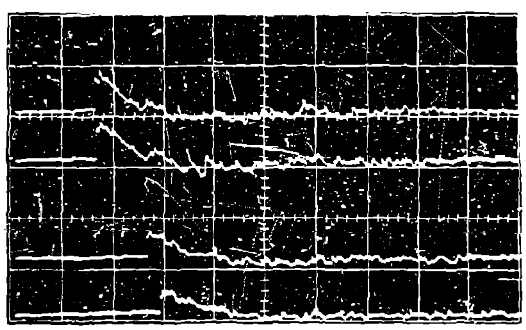
a.
Disc 3 in. Downstream
4.17 psi



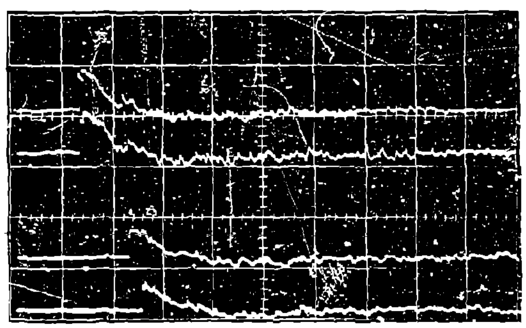
b.
Disc 6 in. Downstream
3.67 psi



c.
Disc 9 in. Downstream
3.17 psi



d.
Disc 12 in. Downstream
3.00 psi



e.
Disc 15 in. Downstream
2.67 psi

Figure 6
Scope Traces of Overpressures Produced by 20 in. Disc at Five Different Locations

TABLE II

EFFICIENCY & OVERPRESSURE DATA

PHASE	BRAKE CONFIGURATION	V_{R1} (fps)	b	ΔP (psi)
1	No Brake	23.68		1.12
	5-K, Medium Efficiency Brake	19.62	1.15	4.48
	M2A2E2, Low Efficiency Brake	20.40	.957	3.36
2 Single Baffle	15 in. dia disc at 3 in. downstream	19.62	.701	3.67
	15 in. dia disc at 6 in. downstream	18.84	.982	3.34
	15 in. dia disc at 9 in. downstream	18.97	.931	
	15 in. dia disc at 12 in. downstream	19.36	.795	2.77
	15 in. dia disc at 15 in. downstream	19.62	.701	2.17
	20 in. dia disc at 3 in. downstream	19.10	.800	4.17
	20 in. dia disc at 6 in. downstream	18.31	1.085	3.67
	20 in. dia disc at 9 in. downstream	18.31	1.085	3.17
	20 in. dia disc at 12 in. downstream	18.70	.943	3.00
	20 in. dia disc at 15 in. downstream	18.97	.840	2.67
	25 in. dia disc at 3 in. downstream	18.84	.780	4.17
	25 in. dia disc at 6 in. downstream	17.79	1.166	3.67
	25 in. dia disc at 9 in. downstream	17.79	1.166	3.34
	25 in. dia disc at 12 in. downstream	18.05	1.070	3.00
	25 in. dia disc at 15 in. downstream	18.31	.973	2.84

TABLE II (Continued)

PHASE	BRAKE CONFIGURATION	V_{R1} (fps)	b	Δ P (psi)
3 Double Baffle	15 in disc at 6 in; 20 in disc at 10 in	18.31	.987	3.33
	15 in disc at 6 in; 20 in disc at 13 in	17.79	1.180	4.00
	15 in disc at 6 in; 20 in disc at 15 in	17.79	1.180	4.00
	15 in disc at 6 in; 25 in disc at 10 in	18.05	.973	3.33
	15 in disc at 6 in; 25 in disc at 13 in	17.53	1.170	3.83
	15 in disc at 6 in; 25 in disc at 15 in	17.53	1.170	3.83
	20 in disc at 6 in; 15 in disc at 10 in	18.05	1.08	3.66
	20 in disc at 6 in; 15 in disc at 13 in	17.53	1.28	----
	20 in disc at 6 in; 15 in disc at 15 in	17.53	1.28	4.16
	20 in disc at 6 in; 25 in disc at 10 in	17.53	1.08	3.66
	20 in disc at 6 in; 25 in disc at 13 in	17.00	1.29	4.16
	20 in disc at 6 in; 25 in disc at 15 in	17.00	1.29	4.16
	25 in disc at 6 in; 15 in disc at 10 in	17.53	1.17	4.33
	25 in disc at 6 in; 15 in disc at 13 in	17.00	1.37	4.33
	25 in disc at 6 in; 15 in disc at 15 in	17.00	1.37	4.00
	25 in disc at 6 in; 20 in disc at 10 in	17.27	1.18	4.33
	25 in disc at 6 in; 20 in disc at 13 in	16.74	1.39	4.33
	25 in disc at 6 in; 20 in disc at 15 in	16.74	1.39	4.00

4 Triple Baffle — There was no measurable change in either efficiency or overpressure when a third disc was added to a double baffle combination.

RESULTS

1. A Discussion of Test Brake Efficiency Results

When the momentum index is plotted versus downstream distance as in Figure 7a, it can be seen that a closely related family of curves exists. As each disc is moved closer to the muzzle, efficiency is increasing from points 15 in. to 9 in. Between points 9 in. and 6 in., however, the momentum index remains somewhat constant and from points 6 in. to 3 in. drops rapidly until at point 3 in. downstream from the muzzle, it is approximately the same for all three discs. This would indicate, as theory predicts, that as each plate is moved upstream, less gas escapes around it; the larger the plate, of course, the smaller the loss. The level portions of the curves between points 9 in. and 6 in. indicates an area where the gases escaping through the projectile port become more appreciable and offset the decreasing gas loss around the disc. It is this trade-off between flows, therefore, which holds the disc's total impulse constant. At 3 in. downstream, the shape of the gas flow allows no gas to escape around the 15 in. disc and, therefore, no further increase in disc diameter will produce an increase in the momentum index. From 3 in. downstream up to the muzzle, the efficiency continues to drop rapidly until at the muzzle, all the gases pass through the projectile port and (b) equals zero.

It can also be seen in Figure 7 a, that the 15 in. disc at is maximum efficiency compares closely to the M2A2E2, low efficiency brake as does the 25 in. disc to the 5-K, medium efficiency brake..

In Figure 7b, the momentum indices for the double baffle brakes are plotted versus distance between the first and second brake. As in the single baffle tests, b remains constant in the region between point 6 in. and 9 in. and at point 3 in., the second disc offers no measurable gain in efficiency. The same explanation as before holds true here. Most of the gases passing through the first disc pass in turn through the second unless the second disc is at least 6 in. further downstream. It also can be seen that an addition of any second disc at 6 in. away increases the overall efficiency approximately 0.20 for every combination. This proves that although a large quantity of gas is escaping through the first disc, there isn't enough to cause gas escape around the 15 in. disc, hence the increase of the second disc diameter causes no further rise in b. Furthermore, for all double brake combinations where the second disc was at least 6 in. downstream from the first, the momentum index was greater than both the 5-K brake and the most efficient single disc.

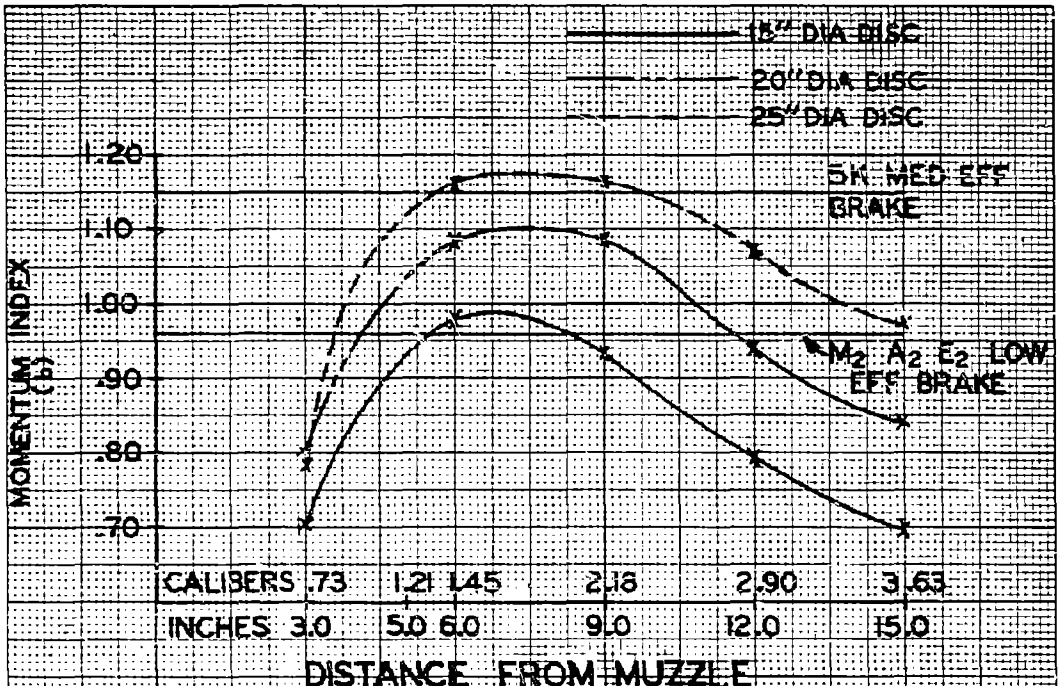


FIG. 7a SINGLE BAFFLE BRAKES

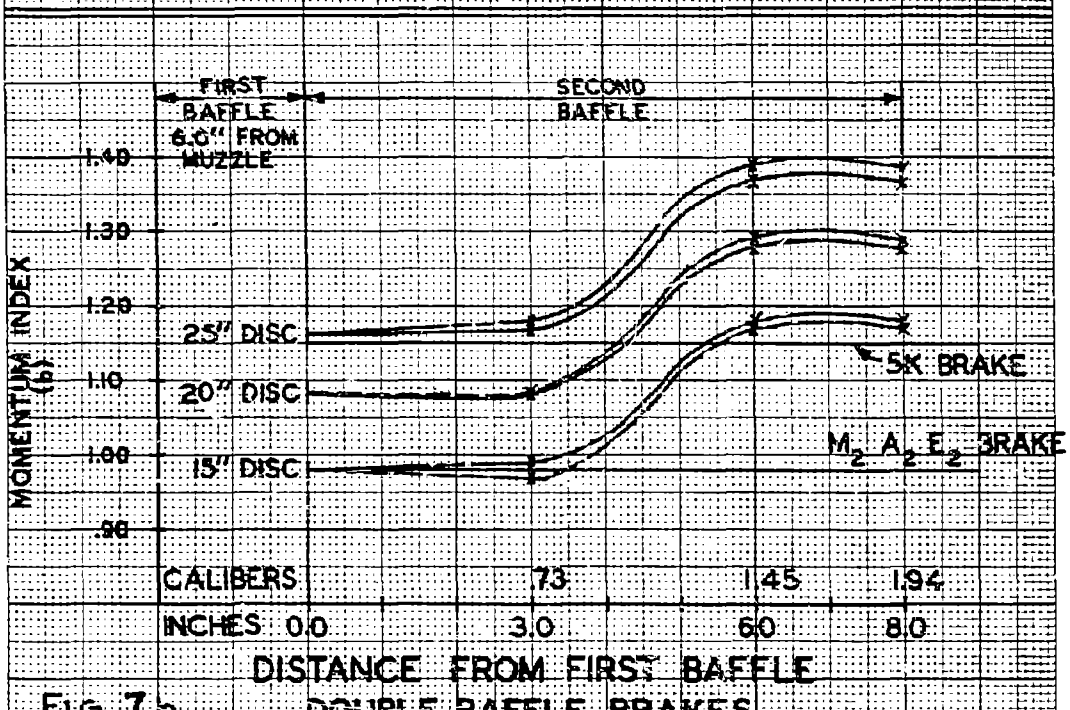


FIG. 7b DOUBLE BAFFLE BRAKES

2. A Discussion of Test Brake Overpressure Results:

In Figure 8a, overpressure (ΔP) is plotted versus distance of the single baffles. It can be seen that the overpressure rises as the disc is moved closer to the muzzle, having its peak at 3 in. downstream from the muzzle which is a point of low efficiency. Also, it should be noted that the disc diameter is not as strong a function of ΔP as it was for momentum index. These two observations indicate that overpressure, unlike momentum index, is primarily dependent upon peak mass rate of gas flow from the brake and not the quantity of gas deflected.

All of the single baffle configurations produced less overpressure than did the 5-K brake and half of them outperformed the M2A2E2 brake in this respect.

Looking now at the overpressure results for the double baffle brakes shown in Figure 8b, one can see that the data doesn't follow the same pattern as that for single discs. Instead of the overpressure rising as the second disc is moved closer to the first, it simulates the efficiency performance and remains constant between points 8 in. and 6 in. dropping off at a point 3 in. downstream. This can be explained by the fact that the first disc acts as a shield between the second disc and the blast gages and as the second disc is moved upstream, less and less gas escapes around the shield in the direction of the crew. The fact that the rise in ΔP is less than the rise in b when a second baffle is added strengthens this theory.

All values of overpressure for the double baffle brakes lie between the ΔP ratings for the 5-K and M2A2E2 brakes.

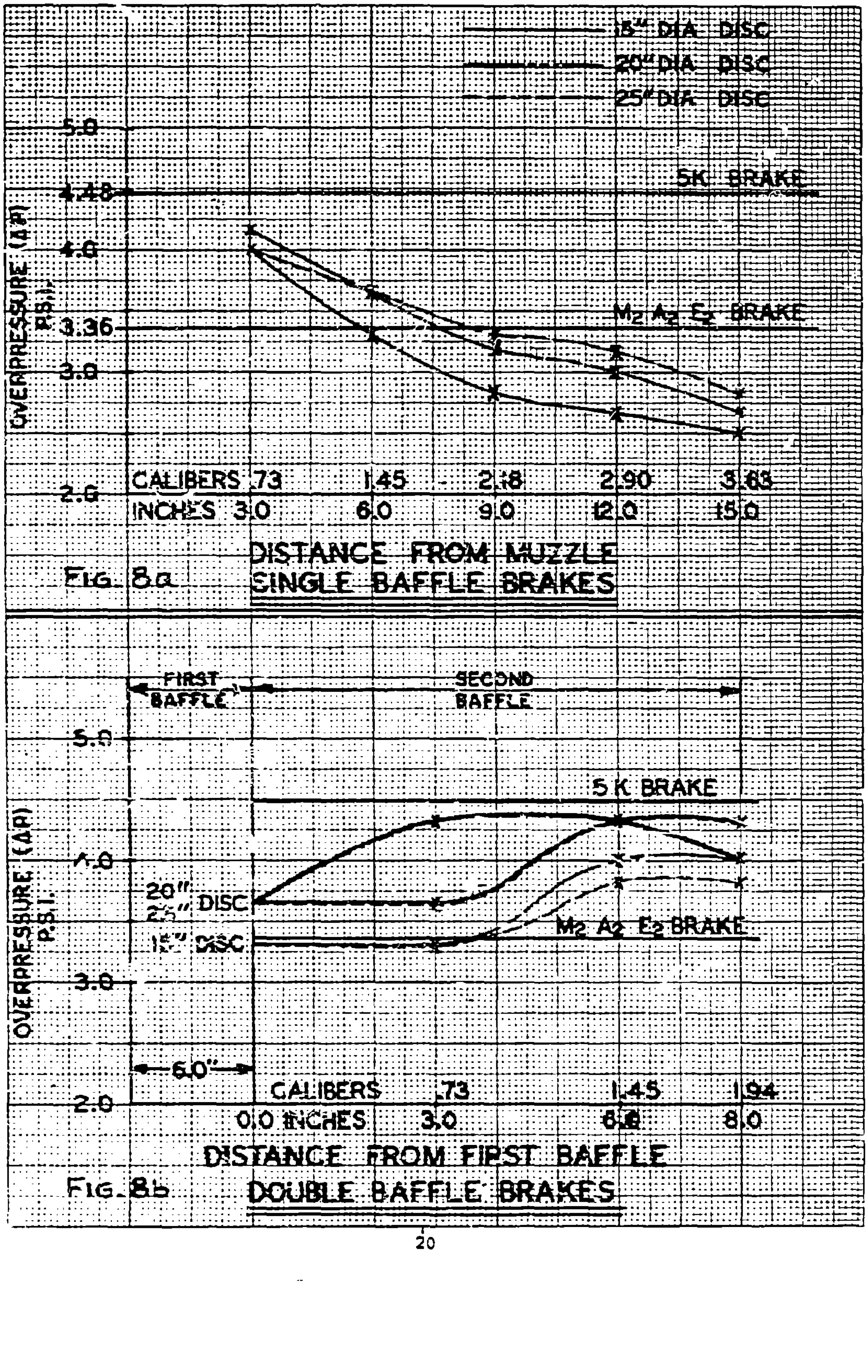
CONCLUSIONS

From this study of the muzzle brake parameters, diameter and downstream distance, the following conclusion can be drawn:

1. The efficiency of a muzzle brake depends primarily on the quantity of gas deflected.

2. The overpressure in the crew area depends primarily upon the peak mass rate of gas flow which in turn is dependent on downstream distance.

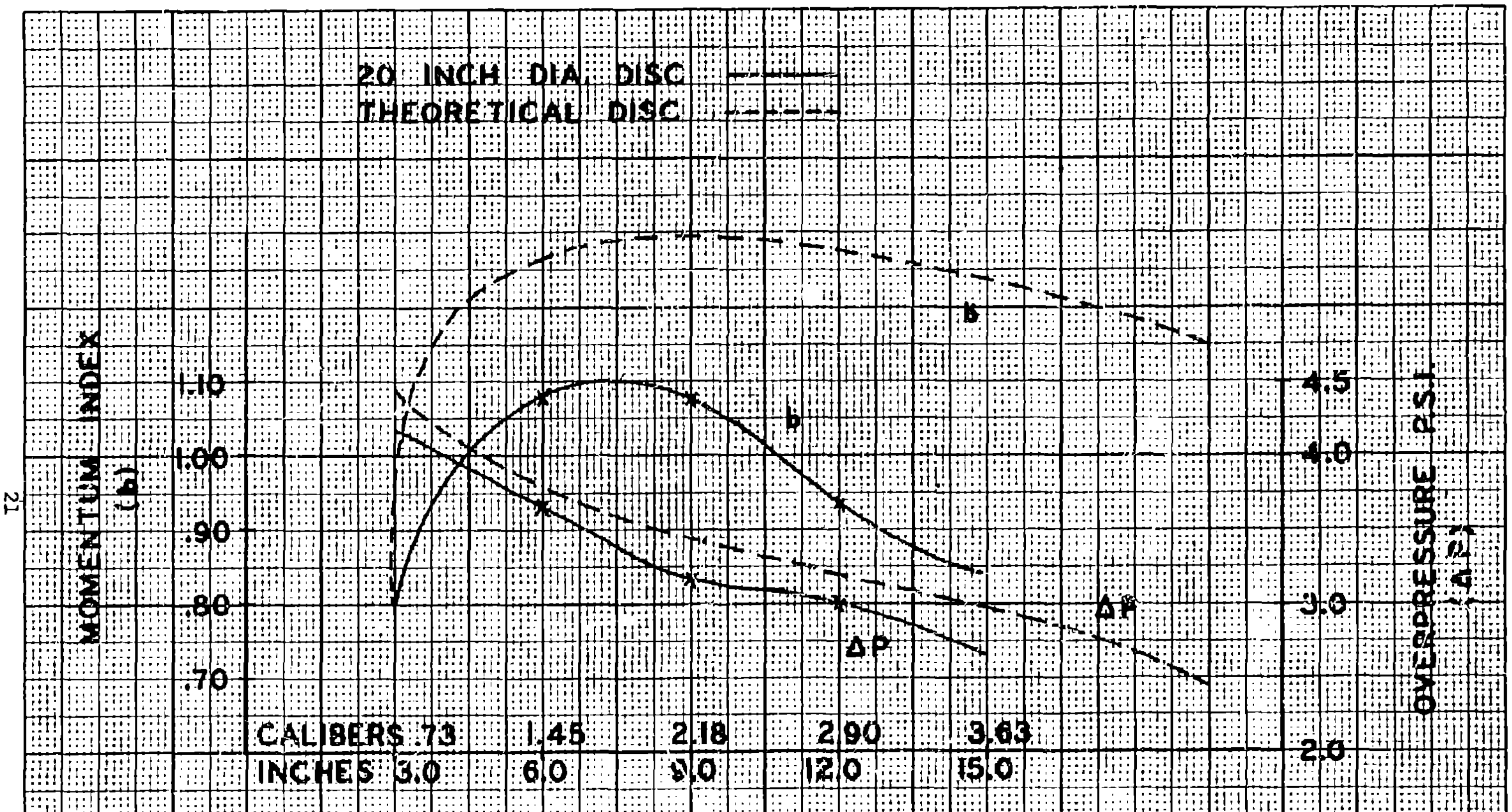
3. From the first two statements and the results of phase 2, one can further conclude that the larger the brake diameter, the farther downstream the compensating effect between gas flow around the brake and through the brake extends. Therefore, from a theoretical standpoint, a very large disc, placed at a great distance from the muzzle would provide both high efficiency and extremely weak overpressures near the crew. This fact is illustrated in Figure 9 where the efficiencies and overpressures for both the 20 inch diameter disc and a hypothetical large disc are plotted versus distance.



15" DIA DISC
20" DIA DISC
25" DIA DISC
5K BRAKE
M2 A2 E2 BRAKE
OVERPRESSURE (ΔP) P.S.I.
5.0
4.48
4.0
3.36
3.0
2.0
CALIBERS .73 1.45 2.18 2.90 3.63
INCHES 3.0 6.0 9.0 12.0 15.0
DISTANCE FROM MUZZLE
SINGLE BAFFLE BRAKES
FIRST BAFFLE
SECOND BAFFLE
5 K BRAKE
20" DISC
25" DISC
15" DISC
M2 A2 E2 BRAKE
6.0"
CALIBERS .73 1.45 1.94
0.0 INCHES 3.0 8.0
DISTANCE FROM FIRST BAFFLE
DOUBLE BAFFLE BRAKES

FIG. 8a

FIG. 8b



EFFICIENCY & OVERPRESSURE

FIGURE 9

4. Since the increase of efficiency is the same for all second disc diameters (See Figure 7b), it can be said that the gas flow to the second disc is never enough to ever justify making the diameter of the second disc larger than the diameter of the first. This is providing, of course, that the first disc is placed within its maximum efficiency range.

5. In the practical design of muzzle brakes, the problem of compromising efficiency with weight can best be met by the use of multi-baffle brakes. This fact is brough out in Figure 7b, where the maximum efficiency of a 25 inch diameter plate is equaled by a combination of smaller plates. The theory here is that each baffle utilizes the gas escaping through the preceeding baffle and the brake as a whole approaches the ideal condition of total gas deflection. Therefore, the more small baffles one can install within a predetermined brake length, the more efficient the brake, providing that the spacing between baffles is such that each brake is at a maximum efficiency location for its particular diameter. The average diameter and length of brake would be predetermined by the weight requirements.

6. The number of baffles that can be put within a given brake length is limited by the minimum amount of spacing that can be tolerated between them. As can be seen in the double baffle test, the second disc added no efficiency when it was only three inches from the first but contributed its maximum when six inches away. Based on this, the minimum spacing between discs would be approximately 1.5 calibers. To shorten this spacing very small diameter baffles would have to be used, say any diameter less than two calibers, the result of which would be a deflecting baffle area too small to obtain any appreciable efficiency.

7. The method described upon, although quite adequate from the standpoint of efficiency, does not alleviate the overpressure problem. Although the test data shows that all the double baffle brakes were more efficient than the 5-K medium efficiency brake and all produced less overpressure in the crew area, it must be remembered that the test brakes used in this study all had a completely open periphery which allowed the deflected gases to expand through a full 360 degrees exit port and that this unhindered expansion of gas helped to increase the efficiency and lower the overpressure. Unfortunately, a completely open periphery also produced intolerable obscuration which makes this type of brake impractical.

8. Although the number of baffles doesn't help to reduce overpressure, the spacing between them can. As can be seen in Figure 9, the overpressure produced by the 20 inch diameter disc decreases 16 percent when the disc is moved from 6 inches downstream to 9 inches while the momentum index remains the same. Therefore, it can be said that in the design of this single or multi-baffled brakes, a small sacrifice in weight in the form of slightly extra length can significantly reduce overpressure.

RECOMMENDATIONS

Because instrumentation limitations, primarily in measuring recoil velocity, made it impossible to measure the impulse produced by small changes in parameters, and because very small error in data can cause a relatively large error in the computation of the momentum index, another measure of efficiency should be used or a better technique of instrumentation be adopted before continuing this muzzle brake study.

Since the momentum index is accepted as the most ideal measurement of efficiency, it is recommended that better instrumentation of recoil velocity be investigated. It is also suggested that less recoil mass be employed. This will increase the recoil velocity and thereby make any measurement error relatively less significant.

APPENDIX

INSTRUMENTATION EQUIPMENT AND PROCEDURES

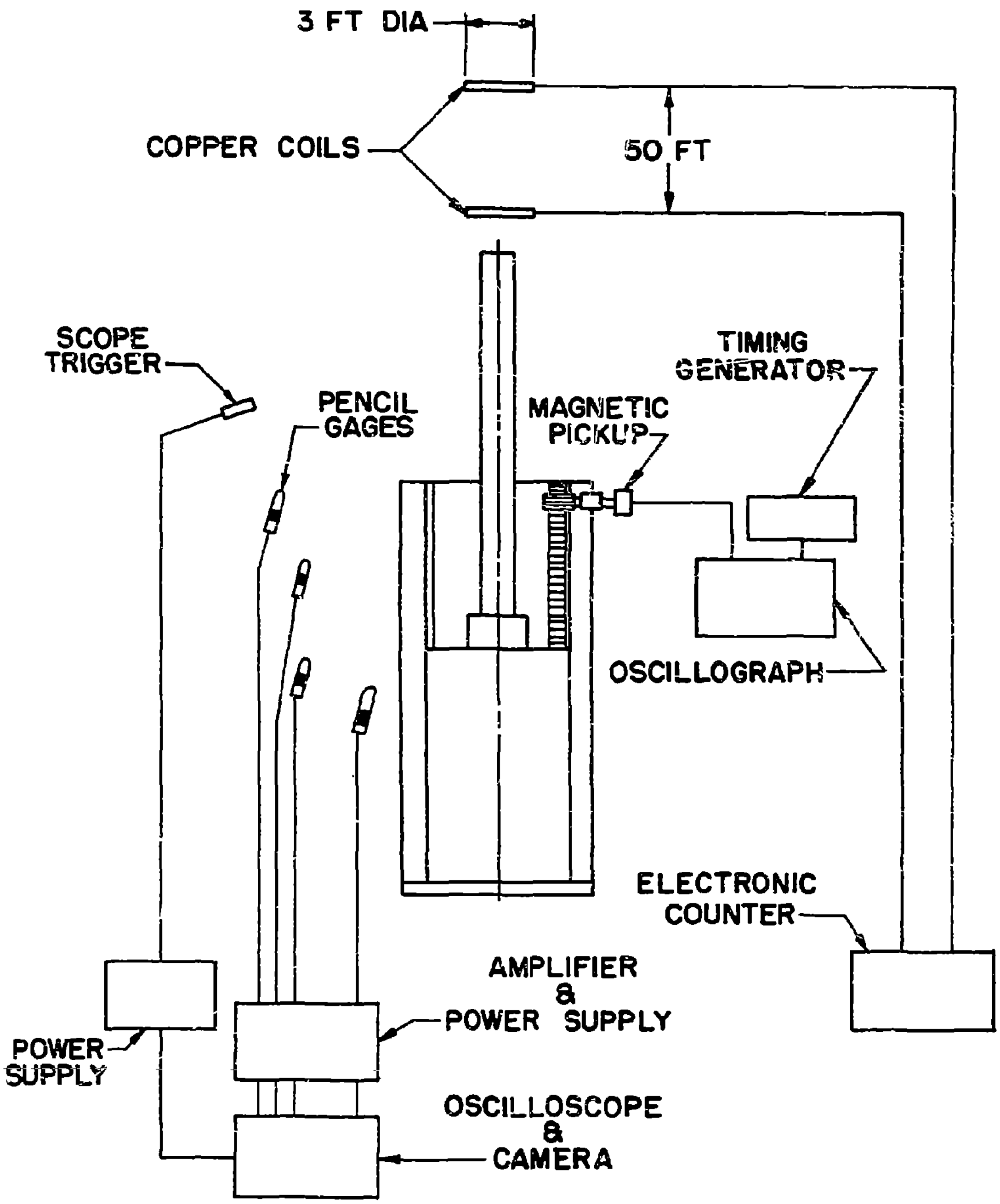
Muzzle Velocity: The muzzle velocity was measured by firing magnetized projectiles through two copper coils, spaced 50 feet apart, which started and stopped an electronic counter (Hewlett-Packard, Model 5233L).

Recoil Velocity: The recoil velocity was measured by a magnetic pickup (Electro Products, Model 3010AN) attached to a rack and pinion gear which in turn was connected between the recoiling parts and the mount. The impulses were recorded on an oscillograph (Honeywell Visicorder, Model 1012). For greater timing accuracy, a timing generator control unit (Armour Research Foundation S/N 12) was also channeled on the oscillograph.

Overpressure Measurement: The instrumentation used to record overpressures is listed below:

Pickups (4)	-	Atlantic Research, Piezo Electric, Pencil Gages
Cables (4)	-	Belden, 8254, RG G 2/V (220 ft. lines)
Amplifiers (4)	-	Atlantic Research, Type 104A
Amplifier Power Supply	-	General Radio Company, Type 1205-B
Plug-ins	-	Tektronic, Type C-A
Oscilloscope	-	Tektronic, Type 551
Camera	-	Tektronic mounted Polaroid
Scope Trigger	-	Preamplifier, Tektronic, Type 122
Trigger Power Supply	-	Tektronic, Type 125

A schematic of the instrumentation is shown in Figure A.



INSTRUMENTATION SCHEMATIC

FIG. A

Pencil Gage Calibration: The pencil gages were dynamically calibrated before each day's firing with the pressure release device shown in Figure B. The gages are placed in the calibrator which is then pressurized to four psi. (Four psi was used because it was the approximate region of the test measurements). A diaphram at one end of the calibrator is then punctured and the impulse of the resulting pressure drop is transferred by the gage, through the same circuitry used in actual testing, to the oscilloscope and camera. A typical calibration trace is shown in Figure C.

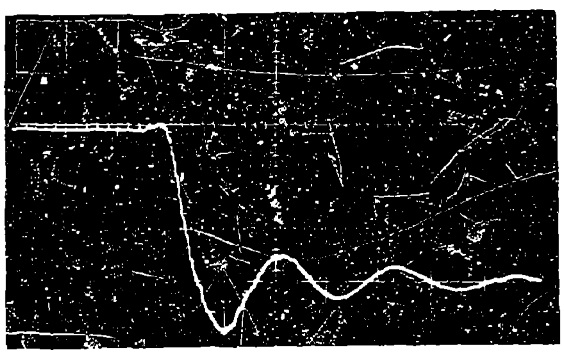
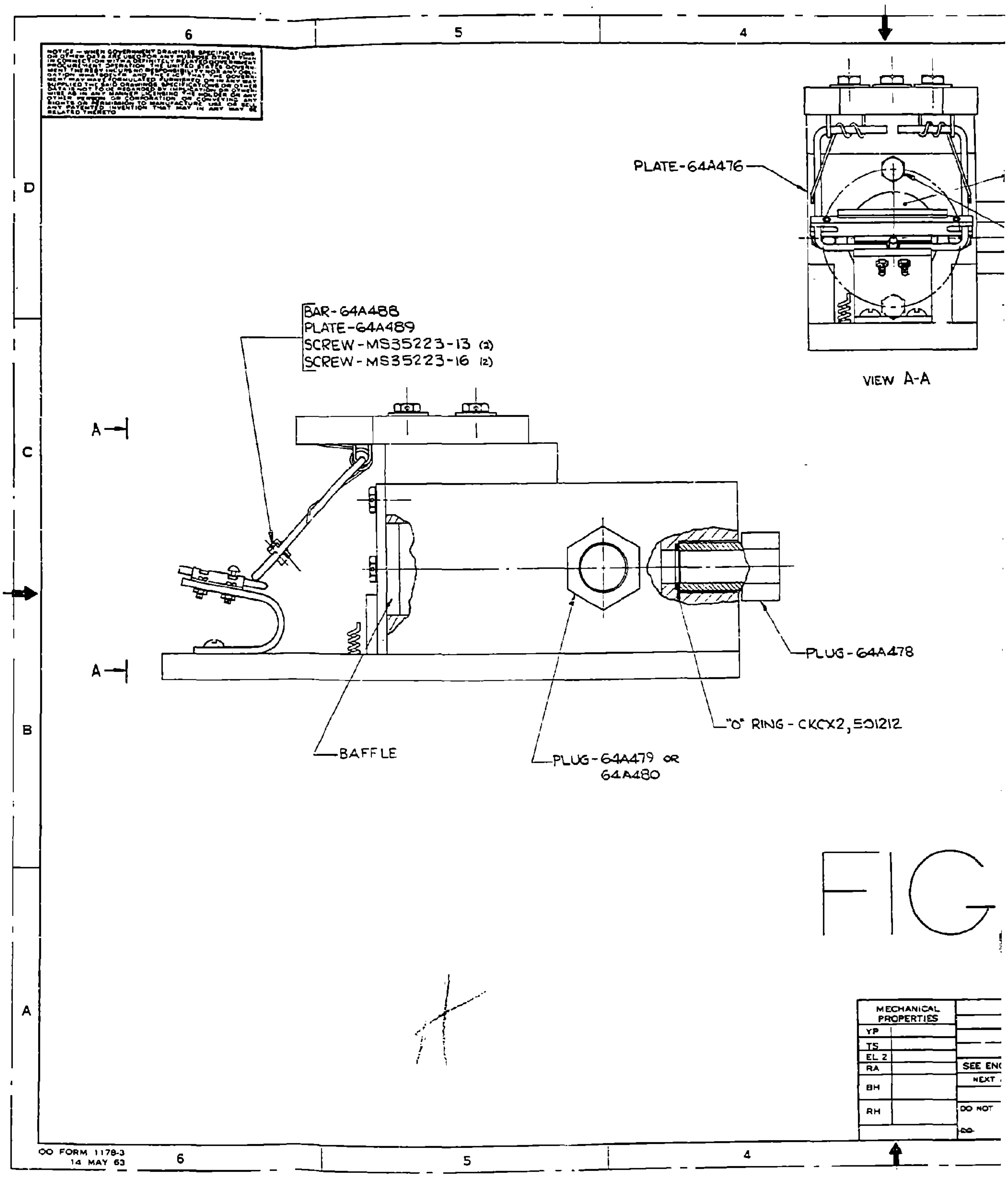


Figure C
Typical Calibration Trace

Calibration Pressure 4 psi
Deflection to Atmospheric Pressure 3 Units
Calibration Factor = 1.33 psi/unit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VIEW A-A
BAR-64A488
PLATE-64A489
SCREW-MS35223-13 (2)
SCREW-MS35223-16 (2)
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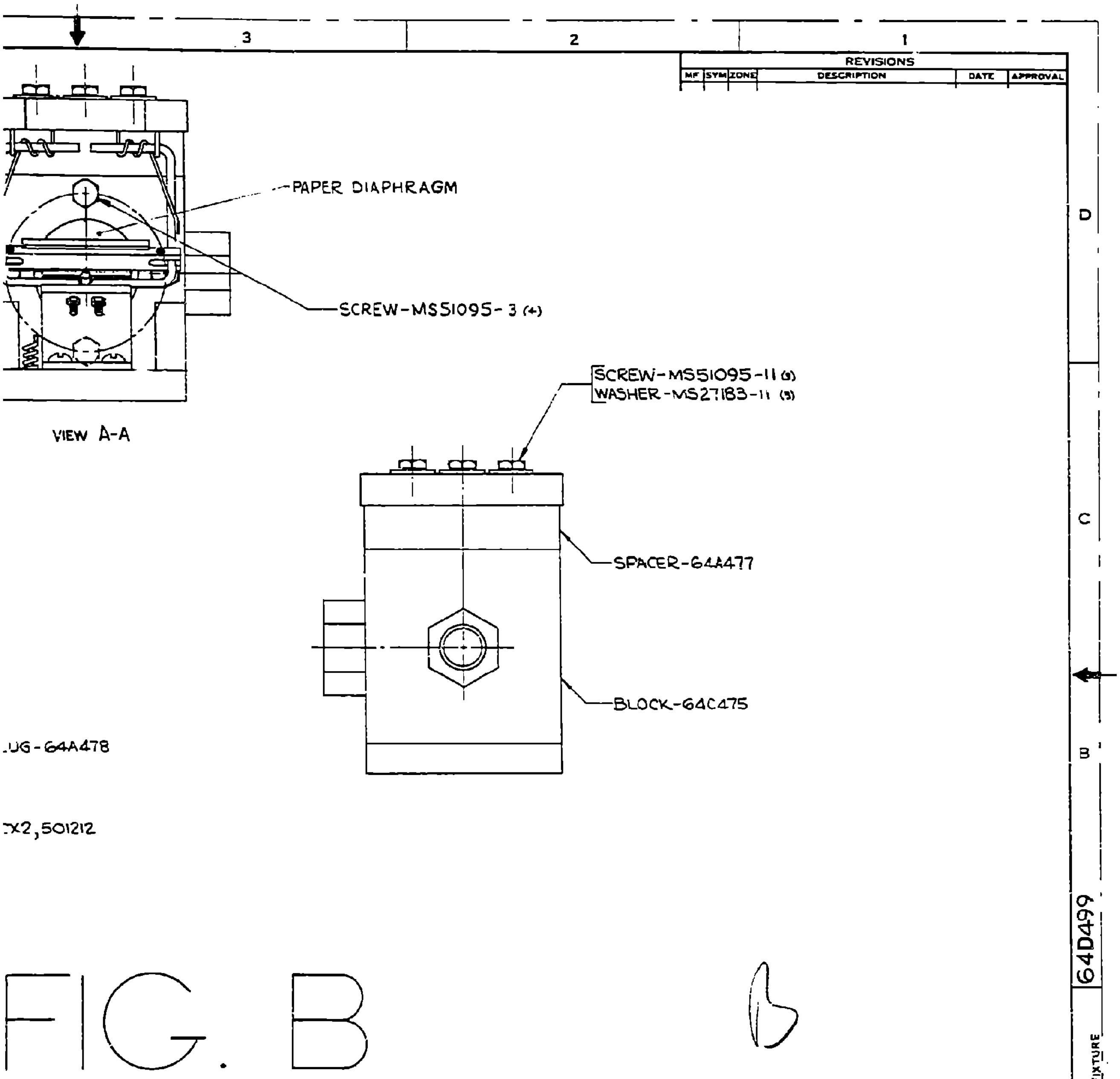

FIG. B

PART NO. 64D499

MECHANICAL PROPERTIES	FIXTURE / CALIBRATION	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	ORIGINAL DATE OF DRAWING JUNE 10, 1964	ROCK ISLAND ARSENAL ROCK ISLAND, ILLINOIS U.S. ARMY WEAPONS COMMAND
YP	SEE ENGINEERING RECORDS	TOLERANCES ON .XX ± — ANGLES ± — .XXX ± —	DRAFTSMAN DUNCAN / CHECKER MJS	1-PENCIL GAUGE CALIBRATION FIXTURE
TS	NEXT ASSY / USED ON	MATERIAL —	TRACER / CHECKER	
EL 2	APPLICATION	HEAT TREATMENT —	ENGINEER MJS / ENGINEER	
RA	DO NOT / APPLY PART NO	FINAL PROTECTIVE FINISH —	SUBMITTED A. M. Ohlsen	CODE IDENT NO. / DWG SIZE D / 64D499
BH	~~DO~~ / ~~AS SPECIFIED~~		APPROVED Arnold A. Kistler	SCALE 1/1 / UNIT WT / SHEET OF
RH				

3 2 1

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None	Rock Island Arsenal

13. ABSTRACT

This is an interim report on an overall study of single and multi-baffled brakes. The intent of this study is to isolate and examine each muzzle brake parameter to determine its effect on efficiency and overpressure for the purpose of developing an optimum brake geometry which will maintain efficiency and reduce overpressures on the crew area. The parameters with which this test dealt were the brake's deflector diameter and its location with respect to the muzzle.

The most important finding of this study is that there exists a downstream loci of points between 1.5 and 2.5 calibers at which a baffle can be placed and maintain a relatively constant efficiency and that at 2.5 calibers, a baffle will produce almost 16 percent less overpressure than it does at 1.5 calibers.

This optimum geometry in which a reduction in overpressure is obtained without loss of efficiency can be applied to all conventional brakes.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Multi-Baffle Brakes						
Parameters						
Single Baffle Brakes						
Brake Geometry						
Gas Flow						
Momentum Index						
Instrumented Firing						
Free Recoil Mount						

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SUPPLEMENTARY

INFORMATION

AD-803 417

The measure of efficiency used for these tests was momentum index (b) which is defined by the following equations:

$$\text{Momentum index (b)} = 1 - \frac{\text{(momentum imparted during gas ejection period with a brake)}}{\text{(momentum imparted during gas ejection period without a brake)}}$$

$$b = 1 - \frac{(M_{R1}\ V_{R1}) - (M_p + M_{c/2})\ V_o}{(M_{R2}\ V_{R2}) - (M_p + M_{c/2})\ V_o} \qquad \text{(Eq. 1)}$$

$M_{R1}\ V_{R1}$ = total momentum imparted to recoiling parts with a brake.

$M_{R2}\ V_{R2}$ = total momentum imparted to recoiling parts without a brake.

$(M_p + M_{c/2})\ V_o$ = Momentum imparted to recoiling parts up to gas ejection period.

where M_{R1} = mass of recoiling parts with a brake.

M_{R2} = mass of recoiling parts without a brake.

M_D = mass of projectile

M_c = mass of charge

correction

V_{R1} = [redacted] non terminal recoil velocity with a brake.

V_{R2} = maximum recoil velocity without a brake.

V_o = muzzle velocity of projectile.

EQUIPMENT

The muzzle brake test fixture used in this study had three (3) removable deflectors or discs. These discs had outside diameters of 15.0, 20.0, and 25.0 inches and inside diameters of 4.25 inches. These were attached by four (4) rods to a muzzle collar and could be positioned at various distances from the muzzle with spacers. (See Figure 1). The test shots were fired from a 105mm howitzer which rolled on the free recoil mount shown in Figure 2. Two conventional brakes were also tested for comparison purposes, the 5K (medium efficiency) brake and the M2A2E2 (low efficiency) brake. (See Figures 3 & 4). Overpressure was measured with piezo-electric pencil gages which were arranged in positions shown in Figure 5. A list of the instrumentation equipment used and procedures followed is presented in the Appendix.